NHSEMH - 2023
2nd National Conference on New Horizons in Science, Engineering, Management and Humanities
International Journal of Scientific Research in Science and Technology
Print ISSN: 2395-6011 | Online ISSN: 2395-602X (www.ijsrst.com)

FEM Based Pavement Performance Evaluation for Potholes

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ABSTRACT

In an effort to give a global view of this field of research, in this paper we highlight the performance of pavement under various pothole conditions. Pavement condition assessment is essential to develop the maintenance and rehabilitation programs. One of the major failures on flexible pavement is potholes. Pothole repairs continue to be a major maintenance problem for many highway agencies. There is a critical need for finding long-lasting, cost-effective materials and construction technologies for repairing potholes.

The main objective of this research effort is to investigate the effect of potholes of different geometry on the performance of flexible pavements. The primary objective is to perform a stress-strain analysis on the potholes using Finite element modeling to individualize the most effective shape for the pothole patchwork. Young modulus is evaluated for the filler materials and the existing material of the pavement to determine their compatibility in different loading scenarios. The behavior of potholes is determined at different depths under a standard static wheel load. The structure is modeled using COMSOL, a finite element analysis software. The analysis results can provide several reasonable and economic suggestions for road design and maintenance to meet the present road maintenance of maintenance requirements.

Keywords: Finite element analysis; Pothole; Pavement performance

I. INTRODUCTION

Flexible pavement consists of many layers but in general, it comprises of Sub-Grade, Sub-Base course, Base course and Surface Course. Any change in these layers results in the failure of the pavement structure and eventually affect its serviceability. It is of utmost importance to construct these layers with high degree of accuracy. Even then, there are different types of failures arises on the pavement structure during its design life. The reasons for these failures are mostly related to ageing, vehicle loads, moisture, temperature variation, as well as their combination. Out of these, the combined effect of moisture with the penetration of water into the layers has the ability to affect the layers and the pavement as a whole. These layers enable the pavement structure to bend, which therefore helps in damage reduction. The distress occurs on the pavement is divided into two groups viz., environmental distress and structural distress. Environmental distress in flexible pavements includes the outside influence that affects the performance of the pavement whereas the structural distress is classified as the physical failures that are found on the pavement surface and the sub-base layer. The reasons for these failures are overloading, frost action, wet sub-grade, etc. Various failures that arise on flexible pavement due to structural distress are Alligator

cracking, depressions, corrugations, shoving, potholes and rutting.

Out of these, potholes are the most common and widely occurring failure. Potholes are developed on the road surface when a part of original pavement gets broken away which then causes a disruption on the surface. Pavement fatigue is the main reason behind this. The interlocking of fatigue cracking leads to the formation of alligator cracks and the loosening and removal of the materials between those cracks due to the continuous action of loads and stresses develops a pothole. The combination of water and traffic loading together leads to the development of a pothole. The freezing and thawing cycles also damage the pavement and creates the openings for the water to penetrate into the layers. Potholes can grow to several feet in width but they are usually shallow in depth. There are various risks associated with the potholes. Vehicle damage due to unexpected jolt is the foremost risk that arises due to the development of the pothole on the pavement surface. This damage in turn can lead to a cascade of mechanical problems and catastrophic human injuries. If the pavement sections are not properly maintained, the environmental and structural factors results in shortening of the design life. Various studies have been carried out to point out the importance of pothole patching. If the size of the pothole is considerably large, then it does not actually affect the vehicle and its performance when compared to smaller potholes. Various patching technique can be used to repair a pothole, but the most common material used is cold mix asphalt or hot mix asphalt. Asphalt binder has its own viscoelastic properties which are a combination of elastic solid and a viscous fluid. This viscoelastic property of the binder is transferred to the mix, resulting in a viscoelastic mix which can be represented by mathematical models. Various studies have focused on the effects of viscoelastic properties of cold mix on pavement repairs. Regardless of the type of material used, concentration of stress at the boundary between the new and the existing material is a major concern. Very few studies are conducted using a 3-dimensional finite element simulation which shows the effects of various pothole geometry on the pavement. The stress reduction based on different geometry of the pothole is also studied. Few other studies have also focused on modeling of pavement materials as well as pavement structure as a whole under various vehicular loads. FEM has been used to simulate variety of conditions and it has also been used to simulate vehicle load interaction with the pavement surface.

In this study, simulations were performed to determine the effect of geometric shapes of pothole patch on the pavement structure. Comparative studies based on different model configurations were carried out to determine the behavior of flexible pavement and its layers. Further research has to be carried out to overcome this gap and to develop a general solution for the pothole patching technique as well.

II. METHODOLOGY

In this study, a 3-Dimensional Finite Element Model is developed using COMSOL Multi physics to check the response of the pothole under direct traffic loads. This study focuses on the influence of different pothole geometry on the stress concentration of the pavement structure.

This research shows the variation of stress and displacement along the pavement layers. It focuses to describe how the different pavement layers are behaving under direct wheel loads. Pothole was generated at the geometric center of the pavement structure and the overall geometry was considered symmetric to X, Y and Z axis so that the developed stress and the pavement response should also be symmetric to reduce the computational time. Finally, the behavior of the pavement is evaluated by measuring the vertical compressive stress and the displacement in the loading direction.

III. RESULTS AND DISCUSSION

The model is analyzed using COMSOL for various geometry of potholes. The stress-strain results are compared to determine the behavior of pavement layers under the traffic loading. In Fig. 1 contour lines are plot to evaluate the intensity of displacement and stress from the loading point and pothole location. Table 1 show the relation between depth of pothole and its displacement when the vehicle loading is directly over the pothole patch.

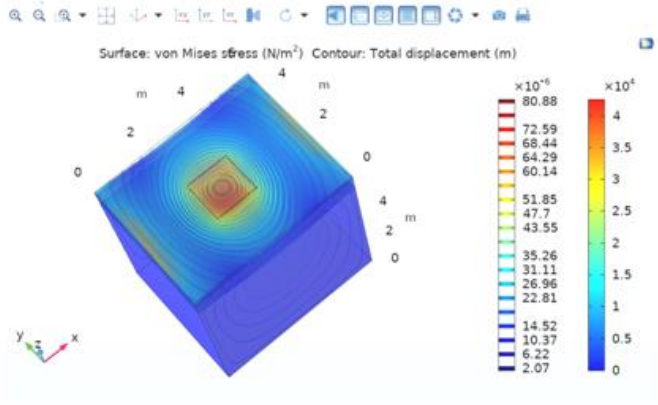

Fig. 1 Stress-Displacement diagram

Table 1 Depth vs. Displacement

Depth (mm)	Displacement (mm)
50 mm	0.081
100 mm	0.083
150 mm	0.087
200 mm	0.091

IV. CONCLUSION

There has been considerable discussion on the topic of stress distribution through various materials in flexible pavement. Studies show that in a layered system the degree of reduction of vertical stresses below the surface is a function of the relative strengths of the two materials.

The Displacement-Depth relation shows that for different geometric shapes, the displacement varies with respect to depth. In this case, the area of the pothole patch was kept constant. Simulations were carried out for different models with varying depth. The behavior of the pavement and its layers is explained in this study using FEM. It was observed that the displacement is directly proportional to the depth of pothole. The patching of pothole is necessary to eliminate the risk of pavement failures due to the presence of moisture and temperature.

Further studies have to be carried out to determine the most favorable shape of potholes to be adopted during patching and repairing process.

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